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Wideband Linear and Nonlinear Distortion Mitigation of a Mismatched Ka-Band Coupled-Cavity Traveling-Wave Tube

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Abstract: Predistortion techniques for correcting the wideband linear and nonlinear distortion in a mismatched coupled-cavity TWT are described. The mismatch in the TWT is caused by previous damage to the circuit.

Keywords: TWTA; nonlinear distortion; mismatch; linearization; predistortion; equalization.

Introduction

Predistortion Linearizers are a simple and effective linearization technique for improving the linearity and efficiency of traveling-wave tube amplifiers (TWTA) [1][2]. Most of the predistortion linearizers, however, are designed to correct narrowband memoryless nonlinearity. In order for predistortion linearization to be effective over wide bandwidth, frequency dependent distortions (both linear and nonlinear) must also be considered. In this report, we will present a study of mitigating wideband linear and nonlinear distortions in a TWT through the use of predistortion. The TWT is a CPI VTA-6430A2 Ka-band coupled-cavity TWT. The small signal gain of the TWT is shown in Figure 1. The gain ripple is thought to be caused by mismatch in the input section which was the result of previous damage to the circuit.

The NRL wideband vector signal generation and analysis system is capable of generating a wide variety of complex wide bandwidth waveforms with an overall system bandwidth of 1.6 GHz [3]. Its major components consist of two baseband generators at 2.4 GSample/s and a digital scope at 20 GSample/s. A software pre-filter network and a software post-filter are implemented as shown in Figure 2 to ensure flat frequency response through the system.

Linear Distortion Mitigation

The system impulse response with the CPI CC-TWT inserted as the device-under-test (DUT) and operating in linear regime is shown in Figure 3. The response function is measured by sending probe impulses through the system. The gain ripple in the TWT manifests itself in time-domain as a secondary pulse about 2.5 ns later than the main pulse. Figure 5 is the corrected system response achieved by adjusting the pre-filter to compensate the frequency response of the TWT. The quality of the corrected response functions are evaluated by the normalized mean-square-error (NMSE) metric given by:

$$NMSE = \sum_{k=1}^{M} \left| r_{k,measured} - r_{k,ideal} \right|^2 \Big/ \sum_{k=1}^{M} \left| r_{k,ideal} \right|^2 \quad (1)$$

where $r_{measured}$ is the measured complex response function, r_{ideal} is the complex ideal response function and k is the sampling index. The complex ideal response function is a sinc function with flat frequency response. The MMSE for the impulse response shown in Figure 4 is about 0.42%.

Linear and Nonlinear Distortion Mitigation

When the TWT is driven nonlinearly, the system impulse response will depend on the amplitude of the impulse drive. The response function obtained from a single probe impulse with a particular amplitude will not completely characterize the system. In order to fully characterize the system, probing the system with multiple impulses of different amplitudes is necessary. It is assumed that this particular CPI CC-TWT can be represented by a filter that represents the frequency response of the TWT and a memoryless nonlinearity as shown in Figure 2. This assumption is justified because the gain ripple is mainly due to internal reflection in the input section. To fully compensate the distortion, the predistortion correction must include both a memoryless nonlinearity and a prefilter. The result of the predistortion correction is summarized in Table 1.

Conclusion

Predistortion configurations more complex than the two-box model described here will also be investigated and reported. This work is supported by the Office of Naval Research.

References

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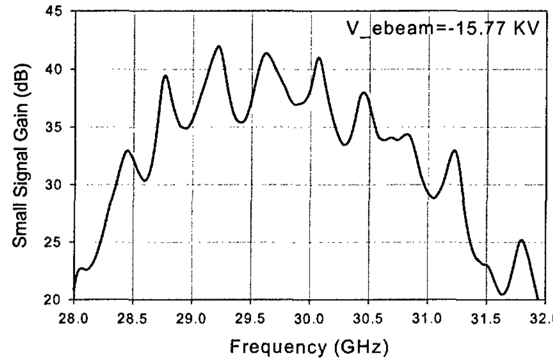

Figure 1. Small Signal Gain of the CPI CC-TWT VTA-6430A2 (Serial No. 006).

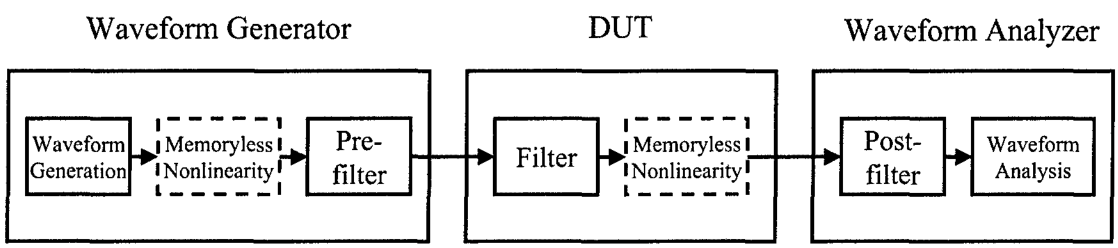

Figure 2. Block Diagram of the Wideband Vector Signal System.

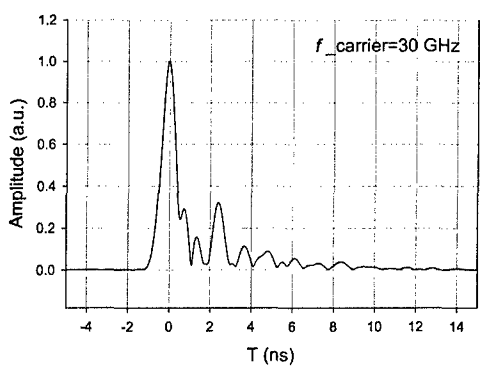

Figure 3. Linear Impulse Response of the Wideband System including the CCTWT.

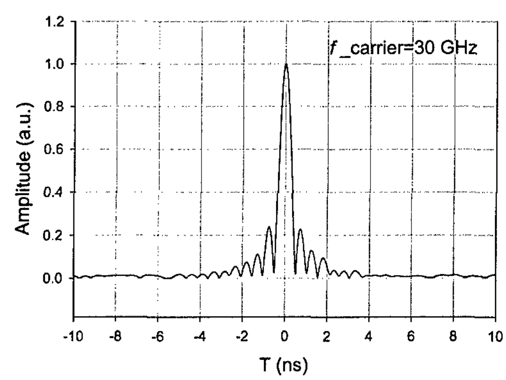

Figure 4. Corrected Impulse Response of the Wideband System including the CCTWT in linear regime.

Table 1. Summary of MMSE

	TWT: Linear Correction: Linear (Single Amplitude Impulse Probing)	TWT: Nonlinear Correction: Linear (Single Amplitude Impulse Probing)	TWT: Nonlinear Correction: Linear (Multi. Amplitude Impulse Probing)	TWT: Nonlinear Correction: Linear & Nonlinear (Multi. Amplitude Impulse Probing)
Corrected Impulse Response MMSE (%)	0.42 %	9.7%	3.46%	1.77%